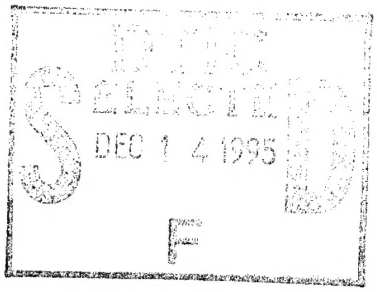
Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035

IHTR 1821
31 August 1995

RECOVERY TECHNIQUE FOR SHOCKED EXPLOSIVE SAMPLES

T.P. Liddiard, J.W. Forbes, J.W. Watt, R.N. Baker, and J. Sharma



REPORT DOCUMENTATION PAGE

Form Approved
QMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	31 August 1995	Final Report

4. TITLE AND SUBTITLE

RECOVERY TECHNIQUE FOR SHOCKED EXPLOSIVE SAMPLES

5. FUNDING NUMBERS

6. AUTHOR(S)

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7. PERFORMING ORGANIZATIONS NAME(S) AND ADDRESS(ES)

Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035

8. PERFORMING ORGANIZATION REPORT NUMBER

IHTR 1821

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
Arlington, VA 22217-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

A technique has been developed to recover explosives that have undergone stresses as high as 26 kilobars. Physical (microscopic) and chemical examination of recovered explosives has led to the discovery of new chemical reactions occurring in these explosives.

14. SUBJECT TERMS

Explosives
Recovery of explosives

15. NUMBER OF PAGES

36

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

FOREWORD

This work was performed for and funded by the Office of Naval Research as part of the Explosives Project within the Explosives and Undersea Warheads Technology Block Program PE602314N. The results and conclusions in this report will be of interest to those seeking information on (1) shock wave sensitivity of explosives, (2) chemistry of recovered shocked explosive samples, and (3) surface chemistry techniques.

The authors wish to acknowledge Jack Marshall for the design of the aluminum frames which held the donor pentolite sphere and samples in place prior to detonation of the donor. Dr. Harold Sandusky and Carl Groves prepared the recovery capsules containing the RDX and CL-20 crystals for experiment 92-R1. Cynthia Forbes typed this report.

Approved and released by:

Ruth Doherty
Head, Detonation Physics Division

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INTRODUCTION

Pre-ignition reactions in explosives subjected to shock compression are of fundamental importance to the study of explosive behavior. Recovery of samples subjected to strong shocks has been a problem. The sample must be contained and remain relatively uncontaminated. Typically, attempts at recovery have resulted in the physical destruction of the explosive test samples due to strong rarefactions and violent collisions with objects such as chamber walls. In addition to the recovery of the explosive sample, some means of determining the shock history in the sample should be available. In most recovery techniques, the impedances of the surrounding materials are quite different from the explosive samples and the confinement is finite in size. Both of these conditions lead to relief waves that significantly affect the strain histories of recovered samples. The use of materials with similar impedances greatly reduces the magnitude of reflected waves within the sample.

In our technique, small (usually 30 mg) explosive samples, encapsulated in Teflon holders, are subjected to strong shock compression. The shock-producing system is the same as that used in the Underwater Sensitivity Test (UST).[1,2] The underwater shock system was carefully calibrated previously.[3] The recovered explosive samples are then removed from the capsules for chemical and physical (microscopic) analysis. Recovery of samples shocked to peak stresses of up to 26 kbar with pulse widths of a few microseconds has been accomplished. The present recovery technique is the result of a number of experiments in which various degrees of success occurred. Modifications after each experiment finally led to a reliable recovery technique.

EXPERIMENTAL TECHNIQUE FOR THE RECOVERY SYSTEM

Donor and Detonator:

In the recovery system, the donor is an 82-mm-diameter sphere of cast pentolite (50% TNT/50% PETN) weighing 470 to 480 g. The spherical charge assembly is shown in Figure 1. The detonator, an RP-80, is an exploding bridgewire type manufactured by Reynolds Industries Systems Inc. It is 7.11 mm in diameter and fits into a 46-mm-deep hole cast (not machined) in the sphere. The RP-80 detonator is insensitive to static discharge and requires at least a 1.0-μF capacitor charged to 2.5 kV to initiate detonation in the detonator. This makes it quite safe for inserting into the pentolite sphere. A 7.0-mm-diameter by 9.5-mm-long pellet of pressed pentolite (density = 1.6 g/cm^3) is inserted in the hole ahead of the detonator to ensure a detonation at the center of the cast pentolite sphere. (Pressed pentolite is much more sensitive to shock than is cast pentolite, the run distance to detonation being negligible and the propagation of detonation being essentially isotropic.) The available space around the detonator leads within the hole is filled with C-4 plastic explosive. A sealant (Duxseal) is used to cover the connection of the plastic sheath, containing the detonator leads, to the pentolite sphere.

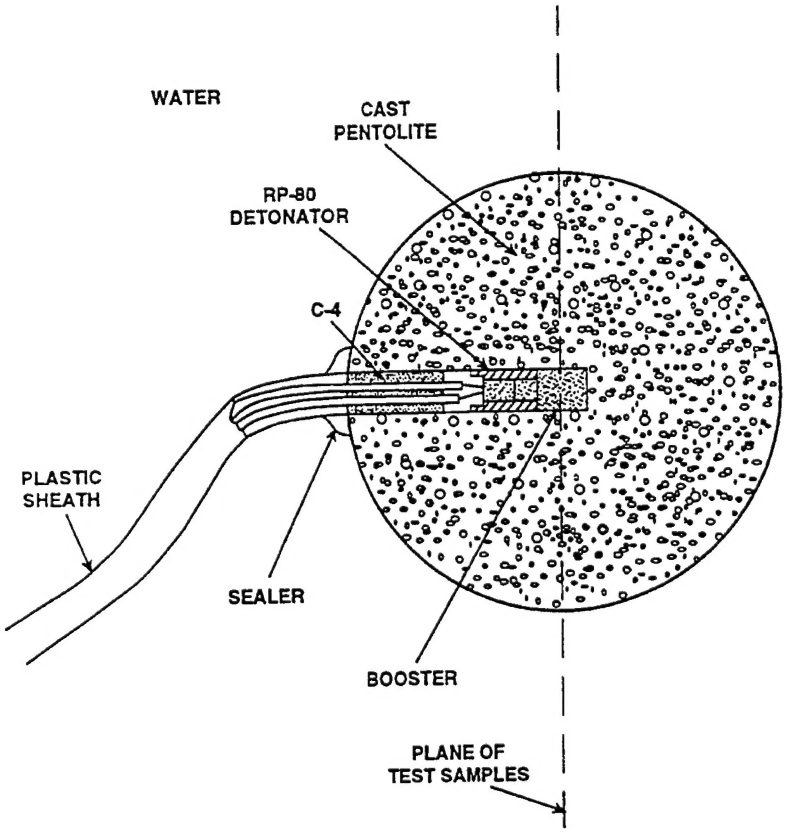

FIGURE 1. SPHERICAL DONOR CHARGE ASSEMBLY

Placement of Components in Tank:

The spherical donor is suspended by a nylon cord harness in a cubic tank of water, 60 cm on an edge. The harness is attached to an aluminum supporting frame. The test samples enclosed in Teflon are mounted in thin-walled steel tubes which, in turn, are fastened to the aluminum frame by Plexiglas holders. The donor is positioned in the tank so that the detonator axis is normal to the plane in which the test samples are usually placed. This orientation reduces irregularities in the shock front since the arrival of detonation at the donor surface is observed to be more symmetrical in planes normal to the detonator axis. The Teflon capsules are oriented so as to present the flat ends toward the center of the spherical donor to ensure as close to one-dimensional loading of the sample as possible. The explosive test samples are set at different distances from the donor to obtain various input pressures. The sketch in Figure 2 shows the general arrangement of the donor and four capsule holders within the tank of water. More test specimens can be added to the arrangement as indicated by the photograph in Figure 3. The extra capsule holders are mounted in holes drilled at an angle in the PMMA holder which was placed in front of the donor sphere.

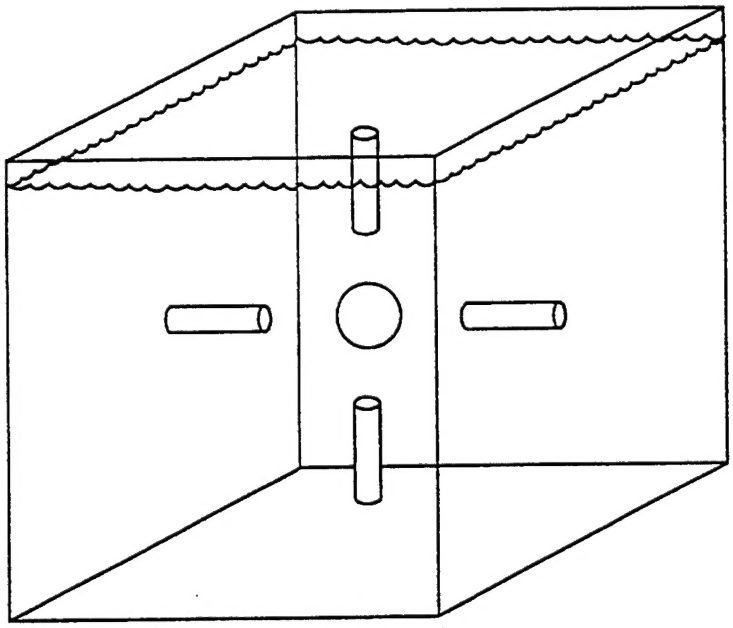

FIGURE 2. CAPSULE PLACEMENT AROUND PENTOLITE SPHERE

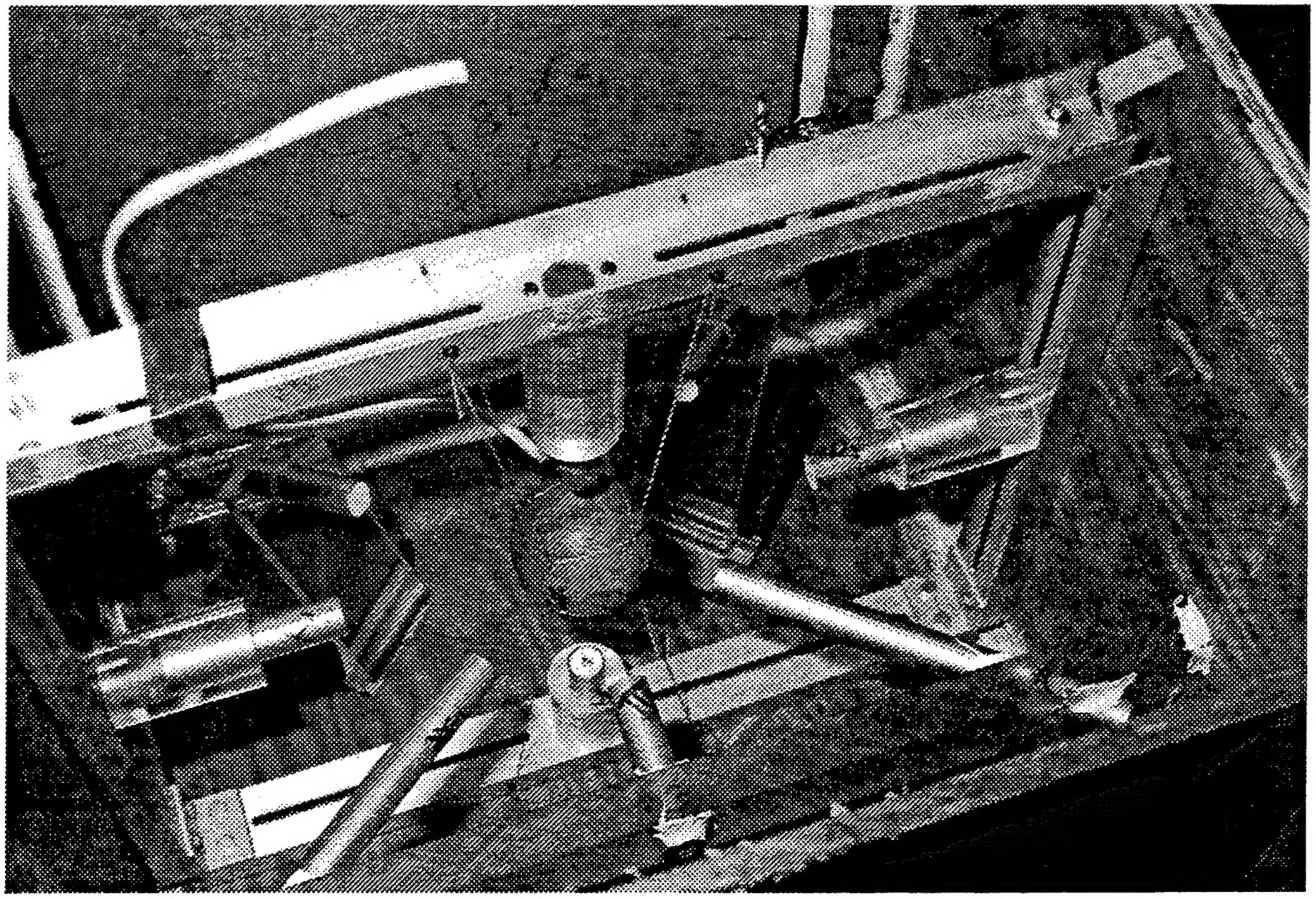

FIGURE 3. PLACEMENT OF NINE TEST SAMPLES IN UNFILLED TANK

Sample Holder:

The Teflon sample holder (capsule) is in two parts—a cap and a threaded rod (plug) with a cavity in one end to accommodate the explosive test sample (Figure 4). A 1.6-mm-diameter bleed hole is located at the end of the cavity in the cap to permit air to escape when the threaded plug is inserted into the cap. In early versions of the test capsule, the plug was threaded along its entire length. However, the plug had a tendency to warp, causing it to bind while being screwed into the cap. This made it difficult to know if the explosive specimen was properly confined with the capsule. As a consequence, the threaded length inside the cap was changed to 19 mm (17 mm for the plug). To seal the sample after assembly, the two parts of the capsule originally were etched chemically to permit bonding with special epoxy. Unfortunately, the bonding was so strong that it made it extremely difficult to recover the test sample. The final design uses the 19-mm-long thread without cement. A pipe thread compound containing Teflon is used to seal the threads. After assembly, the bleed hole is plugged with Duxseal.

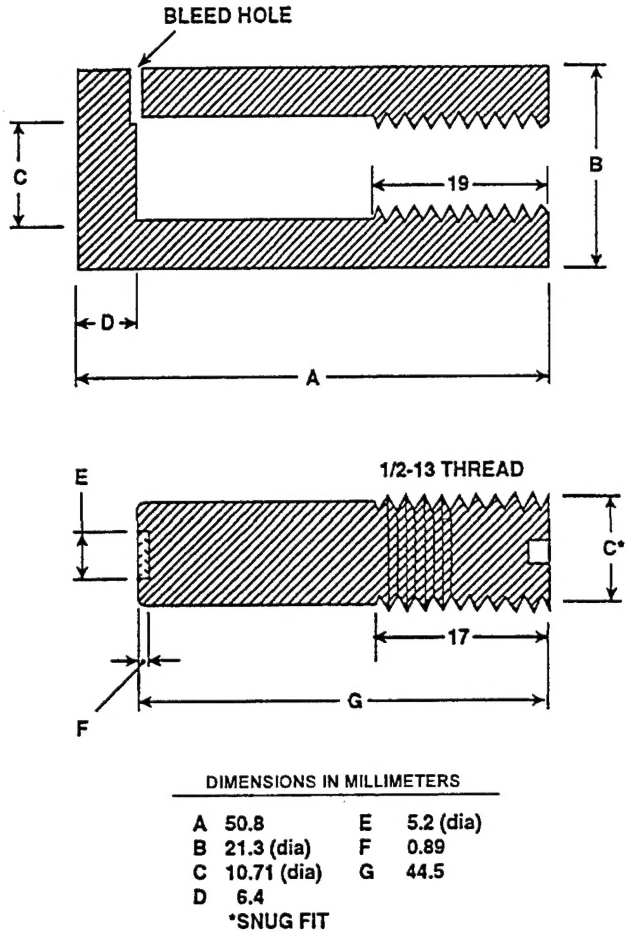

FIGURE 4. TEFLON SAMPLE CAPSULE:
CAP (TOP) AND THREADED PLUG

Support Tube:

The steel support tube is bored out to a diameter which just allows the sample capsule to slide within the tube. The reamed section is just deep enough to allow the capsule to be pushed in flush with the edge of the steel tube. The capsule is held in place by the close fit. The steel support tube has several 2.4-mm holes drilled in the side along its length to permit water to fill the tube completely. A PMMA collar can be made so that the steel support tube can be positioned at any desired angle. The steel support tube arrangement is shown in Figure 5. The length of the PMMA collar, as well as the length of the steel tube, can be such that considerable flexibility in adjustment is possible.

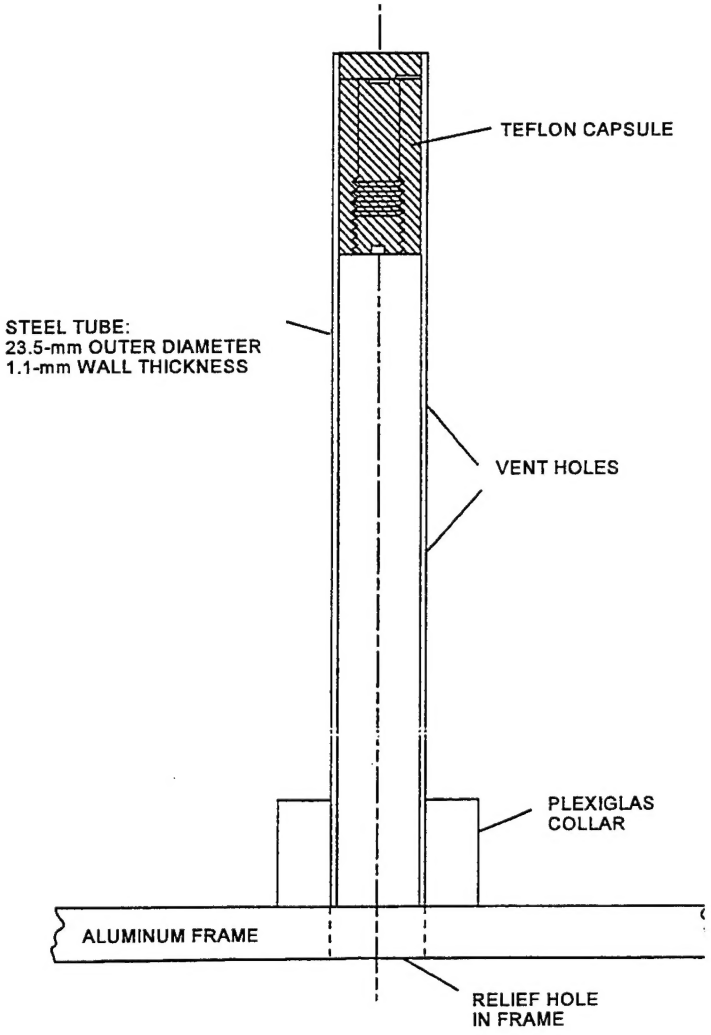

FIGURE 5. CAPSULE HOLDER ARRANGEMENT

Reduction of Capsule Damage:

Although a number of improvements in the recovery system were made during the development period, damage to the capsules remained excessive. Toward the end of the investigation, it was suspected that the impact of the tube against the aluminum frame might be the main reason for the excessive damage. Because of this, holes were cut in the aluminum frame to allow the steel tube to slip through the Plexiglas collar when the shock impacted the tube. Relief holes in the aluminum frame can be seen in Figure 3. This apparently solved the problem since all explosive samples were successfully recovered after this alteration was made.

Shock History of Recovered Sample:

The UST donor used in the recovery system subjects the explosive samples to relatively long low-pressure shocks of spherical geometry. The shock duration is 20 to 40 μs in the water, the duration increasing with distance from the donor.[3] The calibration of the UST[1], i.e., the peak pressure in the water, P_w, as a function of distance from the donor surface, x, is given in Table I. The distance is measured along an imaginary straight line extending outward from the center of the spherical donor.

TABLE I. CALIBRATION OF THE UNDERWATER SENSITIVITY TEST

[The water gap, x_w, is the sum of a number in the first column and a number in the first row. Pressures in kilobars.]

x_w (mm)	0	1	2	3	4	5	6	7	8	9
10	69.48	65.53	61.89	58.53	55.41	52.53	49.86	47.38	45.09	42.95
20	40.96	39.11	37.38	35.76	34.25	32.83	31.51	30.26	29.09	27.99
30	26.95	25.98	25.05	24.18	23.36	22.58	21.84	21.14	20.47	19.84
40	19.24	18.67	18.12	17.60	17.11	16.63	16.18	15.75	15.33	14.94
50	14.56	14.20	13.85	13.51	13.19	12.88	12.59	12.30	12.03	11.76
60	11.51	11.26	11.02	10.79	10.57	10.36	10.15	9.95	9.76	9.58
70	9.40	9.22	9.02	8.89	8.73	8.57	8.42	8.28	8.14	8.00
80	7.87	7.74	7.61	7.49	7.37	7.26	7.15	7.04	6.93	6.83
90	6.73	6.63	6.53	6.44	6.35	6.26	6.17	6.09	6.00	5.92
100	5.84	5.77	5.69	5.62	5.55	5.48	5.41	5.34	5.27	5.21
110	5.15	5.08	5.02	4.96	4.91	4.85	4.79	4.74	4.69	4.63
120	4.58	4.53	4.48	4.43	4.39	4.34	4.29	4.25	4.21	4.16
130	4.12	4.08	4.04	4.00	3.96	3.92	3.88	3.84	3.81	3.77
140	3.73	3.70	3.67	3.63	3.60	3.57	3.53	3.50	3.47	3.44
150	3.41	3.38	3.35	3.32	3.29	3.27	3.24	3.21	3.18	3.16
160	3.13	3.11	3.08	3.06	3.03	3.01	2.98	2.96	2.94	2.91
170	2.89	2.87	2.85	2.83	2.81	2.78	2.76	2.74	2.72	2.70
180	2.68	2.66	2.65	2.63	2.61	2.59	2.57	2.55	2.54	2.52
190	2.50	2.48	2.47	2.45	2.43	2.42	2.40	2.39	2.36	2.35
200	2.34	–	–	–	–	–	–	–	–	–

Highly instrumented experiments would be required to determine the shock pressure-time profile of the small explosive test samples to an uncertainty of ±5%. A second approach to obtaining the stress-time profiles to uncertainties of ±10% would be to run two-dimensional hydrocodes. Since neither of the above approaches have been used, all that can reasonably be done is to determine the peak pressure entering the test samples to uncertainties of ±10% and shock pulse time half-widths to ±20% (see Appendix G of ref. 1).

An example of how the approximate shock history in an explosive sample is determined is as follows. First, the peak pressure in the water, taken from Table I, is plotted as a function of x, as in Figure 6. It is seen that the peak pressure of the spherical shockwave in water is 14.2 kbar just before the shock front contacts the center of the flat surface of the Teflon capsule at x_1 = 50.8 mm. This stress is found to be 19.9 kbar by using standard impedance relations and is shown in Figure 7 for a graphical solution. The shock impedance relationships (shock velocity versus particle velocity) for water and Teflon are taken from ref. 5 and 6 respectively. The peak stress entering the Teflon at x_1 is known to an uncertainty of ±8% according to standard error analysis[4]. Next, the stress in the Teflon capsule at the boundary with a TATB sample prior to the wave entering the TATB, x_2 = 57.2 mm, is 17.0 kbar to within

±10%. It is assumed that the decay of the peak pressure through 6.4 mm of Teflon is proportional to the decay of pressure through an equivalent distance in water, as demonstrated in Figure 6. Finally, the peak pressure entering the TATB sample, 19.0 kbar ± 15%, is determined by using the unreacted shock impedance relation for TATB.[7]

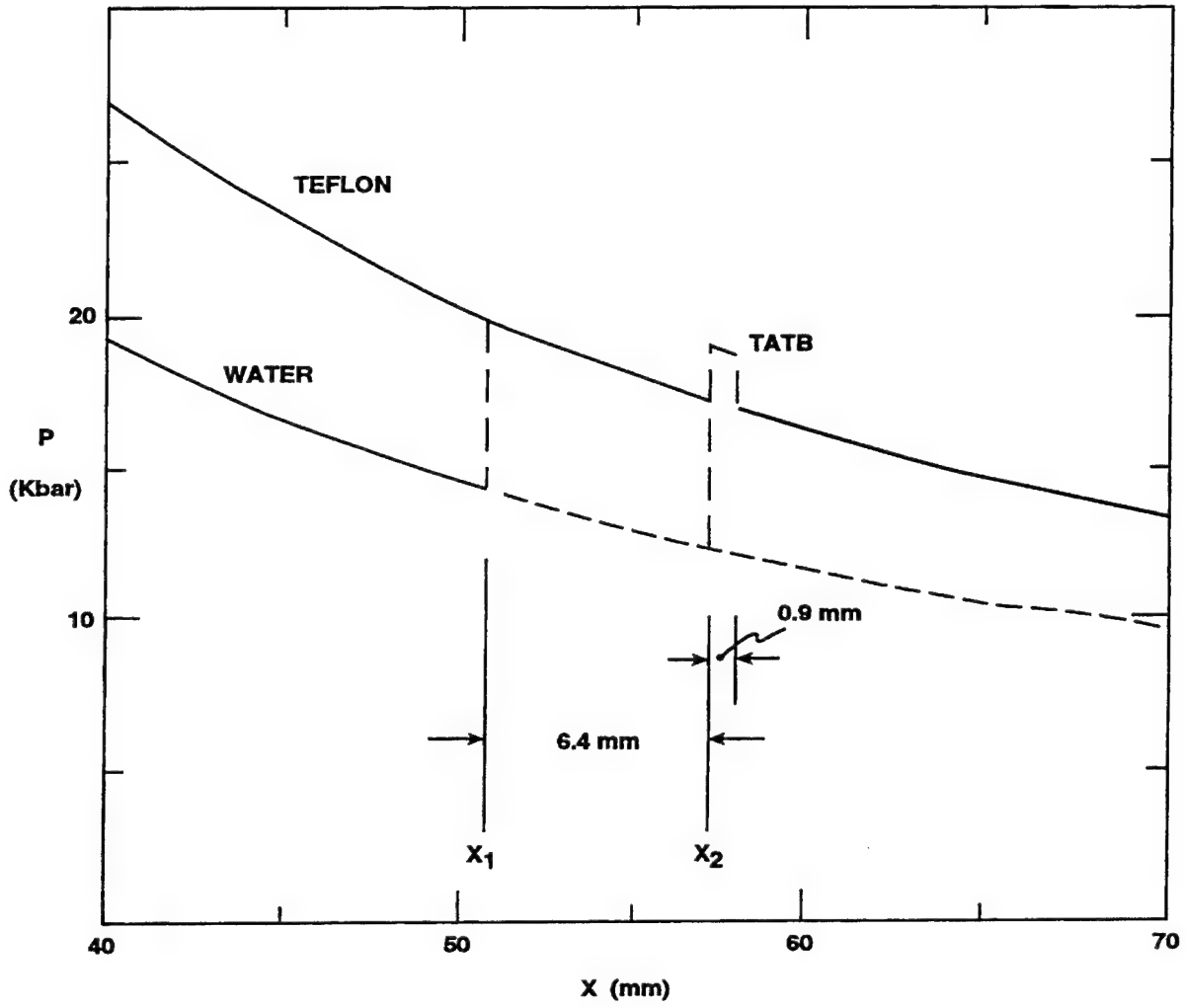

FIGURE 6. METHOD OF DETERMINING THE PEAK STRESS RESEARCHING TO TEFLON AND TATB

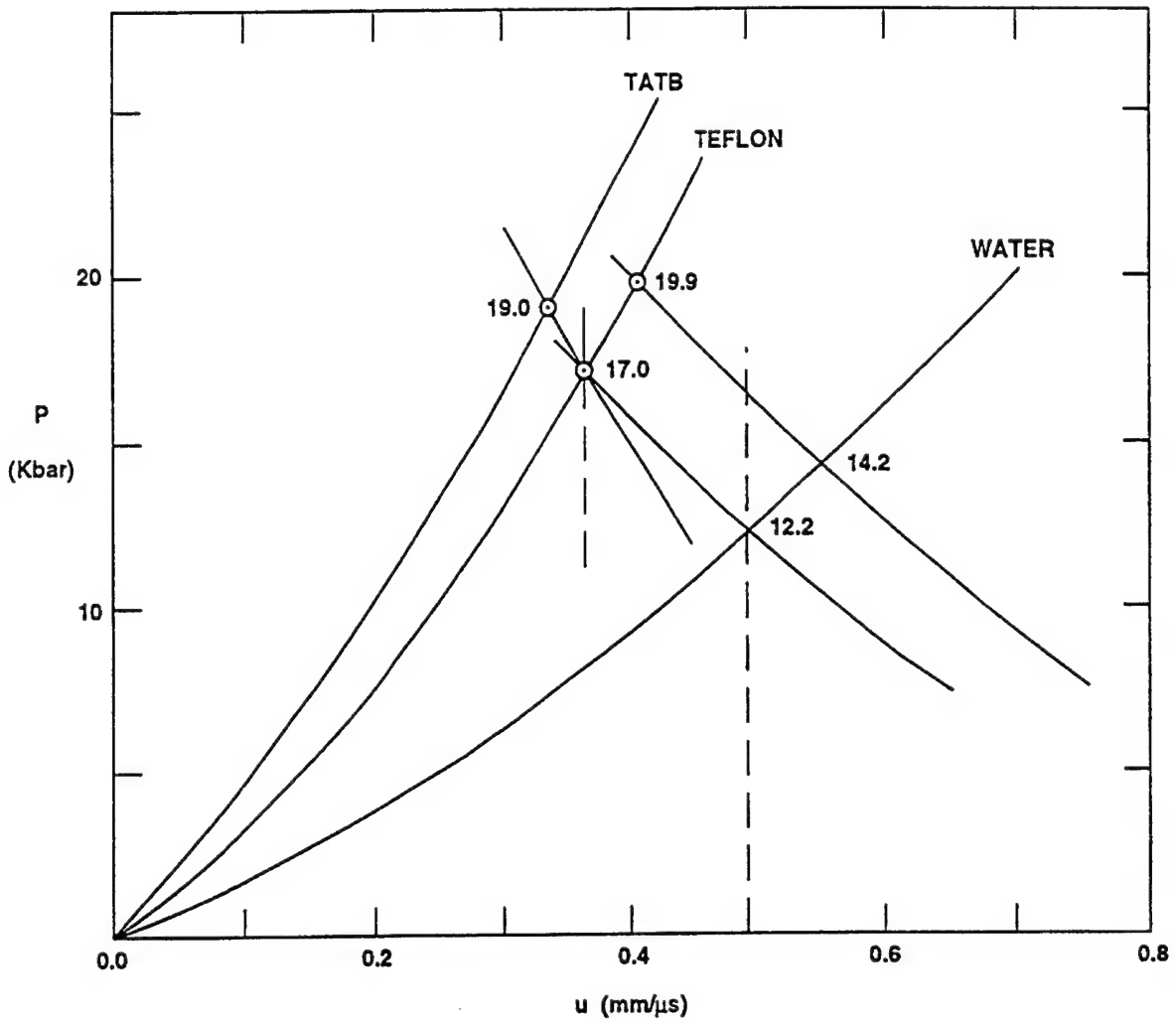

FIGURE 7. GRAPHIC METHOD OF DETERMINING PRESSURES TRANSMITTED TO THE TEFLON CAPSULE AND TATB SAMPLE

Since the Teflon and the explosive have about the same shock impedance, the shape of the stress-time pulse at the center line of the small sample (0.9 mm thick by 5 mm diameter) is primarily limited by the relief waves originating from the Teflon capsules. Assuming the pressure pulse half-width is about equal to the time of travel of the relief wave from the outer radial edge to the center of the Teflon holder gives a pulse half-width of about 5.3 μs (i.e.~ 10.6 mm/[2 mm/μs]).

RESULTS

In Table II are the results of the recovery experiments done to date. A number of papers reported the chemical and physical changes found in some of the samples in the table that were shocked to threshold pressures.[8,9,10,11] In recovered shocked TATB, sub-micron ragged holes were found, accompanied by a fine deposit of furoxan and furazan derivative of TATB. Since the furoxans are more sensitive than TATB, this alteration of the molecule provides a chemical basis of *hot spot* formation and sensitization of the explosive. The furazans are produced by the formation of a water molecule and identified as the first of the exothermic steps in the decomposition reaction of the molecule. In RDX and HMX, the products generated by shock compression are mostly volatile. Analysis of the recovered nitramine material observed a loss of nitro functional groups. In HMX subjected to an underwater shock, a 16% loss of nitro groups was observed.

TABLE II. RESULTS OF RECOVERY EXPERIMENTS

Experiment No.[a]	Sample	Distance capsule is from sphere (mm)	Pressure in Teflon (Kbar)	Results
83-77A	TATB	135	4.9	Sample reacted, no recovery
83-79	TATB	125	5.5	Sample recovered
83-81	TATB(A)	76	10.3	Sample recovered
	TATB(B)	64	13.1	Sample recovered
	TATB(C)	57	14.9	Sample recovered
	TATB(D)	51	17.3	Sample recovered
88-665	HMX(A)	159	4.2	Sample recovered, three pieces found
	HMX(B)	182	3.5	Sample recovered, three pieces found
	HMX(C)	129	5.1	Sample recovered, three pieces found
	HMX(D)	130	5.1	Two pieces found
	NTO(E)	67	12.4	Sample recovered intact
	NTO(F)	49	18.1	Sample recovered intact
92-R1	TNT(I)	100	7.4	Sample recovered
	TNT(II)	120	5.7	Sample recovered
	TATB(III)	50	17.7	Sample recovered
	TATB(IV)	40	22.8	Sample recovered
	RDX crystals(VI)	50	17.7	End blown off capsule, small parts of crystals found
	RDX crystals(VII)	40	22.8	End blown off capsule, no recovery
	CL20/Oil(VIII)	100	7.4	Capsule recovered, soot around air hole, residue found
	CL20/Oil(IX)	150	4.5	Capsule recovered, soot around air hole, residue found

[a]TATB, TNT, NTO, and HMX samples were pressed to 95% to 97% theoretical maximum density.

SUMMARY

A technique has been developed to recover explosives undergoing stresses as high as 26 kbar. Physical (microscopic) and chemical examination of recovered explosives has led to the discovery of new chemical reactions occurring in these explosives.

Improved understanding of this recovery technique results requires two-dimensional hydrocode calculations. These calculations will also give guidance for future improvements of this recovery technique. One obvious improvement would be to replace the steel capsule holders with plastic ones to reduce the impedance mismatch between the capsule holders and the Teflon capsules.

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COMMANDER
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COMMANDER
NAVAL SEA SYSTEMS COMMAND
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WASHINGTON DC 20362-5105 1

COMMANDER
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ATTN SEA 62Z
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COMMANDER
NAVAL SEA SYSTEMS COMMAND
ATTN SEA 91WM
WASHINGTON DC 20362-5105 1

COMMANDER
NAVAL SEA SYSTEMS COMMAND
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505 KING AVENUE
COLUMBUS OH 43201 1

BOEING AEROSPACE COMPANY
ATTN E WILHELM
PO BOX 3707
SEATTLE WA 98124 1

BOEING AEROSPACE COMPANY
ATTN R HELZER
PO BOX 3707
SEATTLE WA 98124 1

COMARCO INC
WEAPON SUPPORT DIVISION
ATTN R SEWELL
RIDGECREST CA 1

CHAMBERLAIN MFG CORP
ATTN J MOSCHEL
550 ESTHER STREET
WATERLOO IA 50704-2524 1

CHAMBERLAIN MFG CORP
ATTN C STROSBERG
550 ESTHER STREET
WATERLOO IA 50704-2524 1

CHAMBERLAIN MFG CORP
ATTN J MEIER
550 ESTHER STREET
WATERLOO IA 50704-2524 1

CHAMBERLAIN MFG CORP
ATTN M BRAMMER
550 ESTHER STREET
WATERLOO IA 50704-2524 1

DYNA EAST CORPORATION
ATTN R WEST
320 ARCH STREET
PHILADELPHIA PA 19104-2588 1

DYNA EAST CORPORATION
ATTN P CHOU
320 ARCH STREET
PHILADELPHIA PA 19104-2588 1

FORD AEROSPACE AND COMM CORP
AERONAUTRONIC DIVISION
ATTN SAM MIGUEL
FORD ROAD JAMBOREE
NEWPORT BEACH CA 92658-9983 1

HERCULES INCORPORATED ROCKET CEN
ATTN G WILLIAMS
PO BOX 210
ROCKET CENTER WV 26726 1

HERCULES
BACCHUS WORKS
ATTN M KLAKKEN
MAGNA UT 84044 1

HERCULES
BACCHUS WORKS
ATTN M BERGER
MAGNA UT 84044 1

HERCULES
BACCHUS WORKS
ATTN G BUTCHER
MAGNA UT 84044 1

HERCULES
BACCHUS WORKS
ATTN L LOSEE
MAGNA UT 84044 1

HERCULES
BACCHUS WORKS
ATTN T SPEED
MAGNA UT 84044 1

HUGHES AIRCRAFT INC
MISSILE SYSTEMS GROUP
ATTN L WEBER
8433 FALLBROOK AVENUE
CANOGA PARK CA 91304-9976 1

KAMAN SCIENCES CORP
ATTN TIMOTHY PENDERGRASS
600 BLVD SOUTH SUITE 208
HUNTSVILLE AL 35802 1

D R KENNEDY ASSOCIATES
PO BOX 4003
MOUNTAIN VIEW CA 94040 1

RADKOWKSI ASSOCIATES
P O BOX 5474
RIVERSIDE CA 92517 1

KORNHAUSER CONSULTING
SERVICES
620 ARGYLE AVENUE
WYNNEWOOD PA 19096 1

LOCKHEED MISSILES & SPACE CO
ATTN R HODGES
PO BOX 504
SUNNYVALE CA 94086 1

LOCKHEED MISSILES & SPACE CO
ATTN J SMITH
PO BOX 504
SUNNYVALE CA 94086 1

LTV AEROSPACE & DEFENSE CO
LTV AEROSPACE PRODUCTS GROUP
ATTN J FLOWERS
PO BOX 655907
DALLAS TX 95265-5907 1

MARTIN MARIETTA CORPORATION
ORLANDO AEROSPACE MISSILE SYS
ATTN H FUEHRER
PO BOX 555837
ORLANDO FL 32855 1

ORLANDO TECHNOLOGY INC
ATTN T KITCHEN
PO BOX 855
SHALIMAR FL 32579 1

RAYTHEON COMPANY
ATTN W ZARR
HARTWELL ROAD
BEDFORD MA 01730 1

S CUBED
A DIVISION OF MAXWELL LABS INC
ATTN R SEDGWICK
PO BOX 1620
LAJOLLA CA 92038 1

ALLIANT TECHSYSTEMS INC
ATTN K L CHRISTIANSON
7225 NORTHLAND DRIVE
BROOKLYN PARK MN 55428 1

ALLIANT TECHSYSTEMS INC
ATTN J L HOULTON
7225 NORTHLAND DRIVE
BROOKLYN PARK MN 55428 1

ALLIANT TECHSYSTEMS INC
ATTN G JOHNSON
7225 NORTHLAND DRIVE
BROOKLYN PARK MN 55428 1

SOUTHWEST RESEARCH INSTITUTE
ATTN C ANDERSON
PO DRAWER 28510
SAN ANTONIO TX 78284 1

SOUTHWEST RESEARCH INSTITUTE
ATTN H GRYTING
PO DRAWER 28510
SAN ANTONIO TX 78284 1

SOUTHWEST RESEARCH INSTITUTE
ATTN A WENTZEL
PO DRAWER 28510
SAN ANTONIO TX 78284 1

SRI INTERATIONAL
ATTN D SHERWOOD
333 RAVENSWOOD AVENUE
MENLO PARK CA 94025 1

SRI INTERATIONAL
ATTN M COWPERTHAWAITE
333 RAVENSWOOD AVENUE
MENLO PARK CA 94025 1

TELEDYNE BROWN ENGINEERING
ATTN L WEBER
PO BOX 070007
HUNTSVILLE AL 35807 1

TELEDYNE BROWN ENGINEERING
ATTN J NEWQUIST
PO BOX 070007
HUNTSVILLE AL 35807 1

TRW
ATTN R CHURCH
SAN BERNADINO CA 92401 1

UNIVERSITY OF DENVER
COLORADO SEMINARY
ATTN G WEEDING
PO BOX 10758
DENVER CO 80210 1

VANDERBILT UNIVERSITY
ATTN A MELLOR
NASHVILLE TN 37235 1

ZERNOW TECHNICAL SERVICES INC
ATTN L ZERNOW
PO BOX 54
SAN DIMAS CA 91773 1

ADVANCED TECH AND RESEARCH INC
LAUREL TECHNOLOGY CENTER
ATTN J W WATT
14900 SWEITZER LANE
LAUREL MD 20707 1

ADVANCED TECHNOLOGY INC
ATTN W SMITH
2121 CRYSTAL DRIVE
ARLINGTON VA 22202 1

ENIG ASSOCIATES INC
SUITE 500
ATTN J ENIG
11120 NEW HAMPSHIRE AVENUE
SILVER SPRING MD 20904-2633 1

SHOCK TRANSIENTS INC
ATTN D DAVISON
PO BOX 5357
HOPKINS MN 55343 1

SCIENCE APPLICATIONS
INTERNATIONAL CORP
ATTN S EIDELMAN
1710 GOODRIDGE DRIVE
MCLEAN VIRGINIA 22102 1

ORLANDO TECHNOLOGY INC
ATTN M GUNGER
PO BOX 855
SHALIMAR FL 32579 1

N M INSTITUTE OF MINING AND TECH
ENERGETIC MATERIALS RESEARCH
AND TESTING CENTER
ATTN P E WILLIAMS
SOCORRO NM 87801 1

HUGHES AIRCRAFT COMPANY
ATTN S W TURNER
P O BOX 3310
FULLERTON CA 92634 1

HUGHES AIRCRAFT COMPANY
ATTN R R RENNER
P O BOX 3310
FULLERTON CA 92634 1

DEFENSE RESEARCH AGENCY
FORT HALSTEAD SEVENOAKS
ATTN LIBRARY
KENT TN14 7BP
UNITED KINGDOM 1

DEFENSE RESEARCH AGENCY
FORT HALSTEAD SEVENOAKS
ATTN M D COOK ET1 BLDG X3
KENT TN14 7BP
UNITED KINGDOM 1

DEFENSE RESEARCH AGENCY
FORT HALSTEAD SEVENOAKS
ATTN A CUMMINGS ET BLDG X59
KENT TN14 7BP
UNITED KINGDOM 1

DEFENSE RESEARCH AGENCY
FORT HALSTEAD SEVENOAKS
ATTN B HAMMANT
KENT TN14 7BP
UNITED KINGDOM 1

DEFENSE RESEARCH AGENCY
FORT HALSTEAD SEVENOAKS
ATTN P HASKINS ET1 BLDG X51
KENT TN14 7BP
UNITED KINGDOM 1

DEFENSE RESEARCH AGENCY
FORT HALSTEAD SEVENOAKS
ATTN G HOOPER
KENT TN14 7BP
UNITED KINGDOM 1

DEFENSE RESEARCH AGENCY
FORT HALSTEAD SEVENOAKS
ATTN D MULLENGER ET1 BLDG X50
KENT TN14 7BP
UNITED KINGDOM 1

ATOMIC WEAPONS ESTABLISHMENT
ATTN LIBRARY
FOULNESS ISLAND
ESSEX SS3 9XE
UNITED KINGDOM 1

ATOMIC WEAPONS ESTABLISHMENT
ATTN H R JAMES
FOULNESS ISLAND
ESSEX SS3 9XE
UNITED KINGDOM 1

MOD(PE)
ATOMIC WEAPONS ESTABLISHMENT
ATTN J JENKINS
ALDERMASTON
READING BERKSHIRE RG7 4PR
UNITED KINGDOM 1

MOD(PE)
ATOMIC WEAPONS ESTABLISHMENT
ATTN B D LAMBOURN
ALDERMASTON
READING BERKSHIRE RG7 4PR
UNITED KINGDOM 1

MOD(PE)
ATOMIC WEAPONS ESTABLISHMENT
ATTN D C SWIFT
ALDERMASTON
READING BERKSHIRE RG7 4PR
UNITED KINGDOM 1

NEC
ATTN W LEEMING
ARDEER SITE
STEVENSTON AYRESHIRE KA20 3LN
SCOTLAND 1

THE BRITISH EMBASSY
BRITISH DEFENCE STAFF
3100 MASSACHUSETTS AVENUE NW
WASHINGTON DC 20008 1

MATERIAL RESEARCH LABORATORY
ATTN M CHICK
PO BOX 50
ASCOT VALE VICTORIA 3032
AUSTRALIA 1

MATERIAL RESEARCH LABORATORY
ATTN D D RICHARDSON
PO BOX 50
ASCOT VALE VICTORIA 3032
AUSTRALIA 1

MATERIAL RESEARCH LABORATORY
ATTN D A JONES
PO BOX 50
ASCOT VALE VICTORIA 3032
AUSTRALIA 1

MATERIAL RESEARCH LABORATORY
ATTN M PODLESAK
PO BOX 50
ASCOT VALE VICTORIA 3032
AUSTRALIA 1

ICI EXPLOSIVES
ATTN D L KENNEDY
GATE 1 BALLARAT ROAD
DEER PARK VICTORIA 3023
AUSTRALIA 1

ORDNANCE BOARD
ATTN R STENSON (S DIV)
EMPRESS STATE BUILDING
LILLIE ROAD LONDON SW6 1TR
UNITED KINGDOM 1

ICI EXPLOSIVES
ATTN J COOPER
STEVENSTON KA20 3LN
UNITED KINGDOM 1

ICI EXPLOSIVES
ATTN G A LEIPER
STEVENSTON KA20 3LN
UNITED KINGDOM 1

ICI EXPLOSIVES
ATTN I J KIRBY
STEVENSTON KA20 3LN
UNITED KINGDOM 1

ORLANDO TECHNOLOGY INC
ATTN M GUNGER
PO BOX 855
SHALIMAR FL 32579 1

CEA
CENTRE D'ETUDES
DE VAUJOURS-MORONVILLIERS
ATTN J N OECONOMOS
B P N° 7 77181 COURTRY
FRANCE 1

CEA
CENTRE D'ETUDES
DE VAUJOURS-MORONVILLIERS
ATTN F CHAISSE
B P N° 7 77181 COURTRY
FRANCE 1

MESSERSCHMITT-BOLKOW-BLOHM GMBH
RESEARCH DEPARTMENT
ATTN M. HELD
8898 SCHROBENHAUSEN
GERMANY 1

DEFENSE RESEARCH ESTABLISHMENT
VALCARTIER
ATTN CONRAD BELANGER
PO BOX 8800
COURCELETTE QUEBEC
CANADA
GOA 1R0 1

DEFENSE RESEARCH ESTABLISHMENT
VALCARTIER
ATTN ROCCO FARINACCIO
PO BOX 8800
COURCELETTE QUEBEC
CANADA
GOA 1R0 1

DEFENSE RESEARCH ESTABLISHMENT
VALCARTIER
ATTN IRENE HOOTON
PO BOX 8800
COURCELETTE QUEBEC
CANADA
GOA 1R0 1

DEFENSE RESEARCH ESTABLISHMENT
VALCARTIER
ATTN GRANT MC INTOSH
PO BOX 8800
COURCELETTE QUEBEC
CANADA
GOA 1R0 1

Internal:

TDE (S MITCHELL) 3
102 1
40D (E JOHNSON) 1
40 1
410 (R GRANDE) 1
410 (R GARRETT) 1
410 (W FURR) 1
410 1
450 (O PARRENT) 1
450 (L LIPTON) 1
460 (J GASPIN) 1
460 (G HARRIS) 1
460 R TUSSING) 1
460 (R BARASH) 1
460 (T FARLEY) 1
460 (W MCDONALD) 1
460 (H MAIR) 1
90I 1
90H 1
90 1
90E 1
90D 1
90C 1
910 (Y TRAN) 1
910 (SITZMANN) 1
910 1
912 (D CICHRA) 1
920 1
930 1
940 1
941 (A DUONG) 1
941 (C GOTZMER) 1
941 (L NOCK) 1
941 (E ANDERSON) 1
950 (L MONTESI) 1
950 (M SWISDAK) 1
952 (J LAIB) 1
954 (L DAVIE) 1
8510 3
8530 3
920C1(R BERNECKER) 1
920C2 (J FORBES) 9
9210 (P MILLER) 1
9210 (H JONES) 1
9210 (C COFFEY) 1
9210 (R GUIRGUIS) 1
9210 (F ZERILLI) 1
9210 (D WOODY) 1
9220 (W WILSON) 1
9220 (C RICHMOND) 1
9220 (D TASKER) 1
9220 (T LIDDIARD) 1
9220 (P GUSTAVSON) 1
9220 (RICHARD LEE) 1
9220 (R BAKER) 1
9230 (G SUTHERLAND) 1

420 (B PARK)	1
420 (W WALKER)	1
420 (A DARE)	1
420 (H CHEN)	1
420 (D BETANCOURT)	1
420	1
9230 (E LEMAR)	1
9230 (J DAVIS)	1
9240 (B GLANCY)	1
9311 (K NEWMAN)	1
9410K (J CHANG)	1
9410 (P DENDOR)	1